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THE BREEDING BIOLOGY AND ADVERTISEMENT CALL OF *LITORIA SPLENDIDA* TYLER, DAVIES & MARTIN

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Summary

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Breeding biology and description of the advertisement call of *Litoria splendida* are presented. Analysis of a call of *L. caerulea* is also provided and shows that these similar, syntopic species have structurally similar calls and thus presumably show significant acoustic interactions in mixed choruses.

KEY WORDS: *Litoria splendida, Litoria caerulea*, frogs, calls, breeding biology.

Introduction

Litoria splendida Tyler, Davies & Martin, 1977, is one of the largest [adult body length 82 - 106 mm (Tyler 1992)] and most beautiful Australian frogs. The species is thought to be sparsely distributed throughout the widespread escarpment country of the Kimberley Division of northern Western Australia (Tyler 1992). *Litoria splendida* is notable for: hypertrophied parotoid and rostral glands (Tyler & Davies 1993), a characteristic it shares with senescent members of the closely related *Litoria caerulea*; an ability to utilize glandular secretions as a waterproof covering (Tyler & Davies 1993); and the production of pharmacologically active caerins in the skin secretions (Tyler & Davies 1993).

What little is known of the reproductive biology of *L. splendida* is based on reproduction by captive individuals (Tyler 1994). In an aquarium, a female laid 2000 eggs, depositing them in discrete clumps of up to 200 eggs, which Tyler (1992) has suggested may reflect an adaptation of females in the wild to lay batches of eggs in several temporary ponds to maximize the likelihood of at least some of the offspring surviving the larval stage. Maximum length of the tadpoles was 54 mm (Tyler 1992).

Litoria splendida is known to call, and presumably breed, after heavy rains in the early wet season (C. Done, Department of Conservation and Land Management Kununurra unpub. obs.). During the numerous field trips to the Kimberley Division undertaken by one of us (GFW) and colleagues from the University of Adelaide over the past 20 years, however, calls of the species have never been heard nor has breeding been observed. In fact, the species is rarely encountered except when associated with artificial habitats, for example toilet blocks, where cool, moist sites are readily available (Tyler 1992).

During January, 1997, we visited the Kununurra area and encountered a breeding chorus of *L. splendida*. Here we describe the call of the species and provide brief notes on associated behaviour, and also a description of the call of syntopic *L. caerulea*, a phylogenetically closely related and ecologically similar species.

Methods

Recordings of calls of *L. splendida* were made using a Sony TCD-5PRO cassette recorder (tape speed 4.76 cm s^{-1}) and Beyer M-88 cardioid dynamic microphone. For comparative purposes, one call of a syntopic *L. caerulea* was obtained from a video sequence of the breeding chorus (Canon Digital camcorder; Hi 8 mm tape). Air wet-bulb temperatures (the effective temperature of frogs calling on land) were measured at the calling site of each individual using an electronic thermistor thermometer (Takara Digimulti Model D611). Recordings were analysed on a DSP 5500 digital Sona-Graph (Kay Elemetrics Corp.) using the in-built set-up #10 [sampling rate (samples sec^{-1}): 10240; frequency range: 4 kHz] with playback on a Nakamichi Dragon cassette recorder. Overall variations in tape speed (i.e. from recording to playback) are estimated at less than 0.5% and frequency responses of all audio-electronic components are close to linear within the relevant frequency range (based on manufacturers' specifications).

For each call, three primary attributes were determined: (i) duration, as the interval from the beginning of the first pulse to the end of the last pulse (ms); (ii) number of pulses per note (direct count); and (iii) dominant frequency (Hz), as the maximum

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value of the spectrum of power across the whole call. In addition, a derived characteristic, pulse repetition rate (pulses s^{-1}), was calculated as 1000 (n-1 pulses)/duration in ms. Levels of resolution were less than 1 ms for temporal characteristics and less than 40 Hz for frequency.

Because there is no possibility of misidentifying these large and distinctive frogs and in the interests of their conservation, voucher specimens of recorded males were not taken. Video and 35-mm-photographic records of the calling males were obtained.

Results and Discussion

Breeding site and breeding behaviour

Breeding and calling were observed, following heavy afternoon rain, on the night of 18.i.1997 in an area of sandstone escarpment adjacent to a large, temporary pond near the main car park within the Hidden Valley National Park, Kununurra WA. The pond was formed within an ill-defined watercourse that ran along the base of the cliffs and was fed by run-off from a number of temporary waterfalls that flow down the cliff face after heavy rainfall. Occasional calls of males at other nearby sites were heard but chorus behaviour was confined to this one site. Four species of frogs, *Litoria splendida*, *L. caerulea*, *L. rubella* and *Limnodynastes ornatus*, were calling around the pond. Amplectant pairs of *L. splendida* and *L. caerulea* were observed in and around the pond. No pairs of the other two species were seen, although no exhaustive search was carried out. The foamy egg masses of *L. ornatus* were scattered over the pond as were large, floating, single-layered sheets of hylid eggs, presumably those of *L. splendida* and *L. caerulea*, although we did not observe any pairs of either species depositing eggs. Nevertheless, contrary to the suggestion of Tyler (1992), on this occasion all *L. splendida* would, of necessity, have deposited their entire egg complement in the one pond because no other aquatic habitats were available in the vicinity of the chorus.

Males of *L. splendida* called from exposed positions either on the near-vertical cliff face or on natural ledges upon the rocky surface. The two recorded males were calling approximately 1.5 and 2 m, respectively, above the pond. Several other individuals and amplectant pairs of *L. splendida* were observed in similar positions. Males of *L. caerulea* called from similar sites on the rock face as well as from elevated positions in surrounding trees and on the ground near the pond. *Litoria rubella* called from ground-level sites near the pond and *Limnodynastes ornatus* called whilst floating in the water.

Although we did not observe pair-formation or egg-laying, pairs of *L. splendida* can remain in the mating embrace for prolonged periods, at least up to 24 h. We observed several amplectant pairs sitting in the open, or in cliff-face crevices, throughout daylight hours before the night of chorus activity described above. Presumably these frogs had entered amplexus during the previous night.

Description of call

A wave-form display and spectrogram of the call of *L. splendida* are shown in Fig. 1. Table 1 lists the values of measured call attributes. The call is a long, pulsed and apparently well-tuned call that is regularly repeated (maximum call rate observed was 56 calls min^{-1}). The call is broad-band but has a tonal quality because its relatively high pulse rate (which exceeds the temporal resolution of the human auditory system and hence our ability to detect pulses at this rate) is perceived as a complex tone. The call is characterized by a very slow rise in amplitude with a rapid cut-off after maximum intensity is reached. The calls of both individuals displayed a number of frequency peaks in the power spectrum (Fig. 2, Table 1) with an inter-peak interval

TABLE 1. *Summary of call attributes of* Litoria splendida *recorded in Hidden Valley National Park, Kununurra, Western Australia.*

Values are based on analysis of five calls of two individuals. Frogs were calling on a sandstone cliff face between 1.5 and 2 m above a pond. Temperatures at the calling site were A_D= 25.5° C and A_W= 25.1° C. Values for the first three attributes show the mean and range (in parentheses).

Individual	Call Duration (ms)	No. of Pulses	Pulse Repetition Rate ($p\ s^{-1}$)	Dominant Frequency (Hz)	Other Notable Frequencies (Hz)
Cut #1	666.4 (625-703)	82.8 (79-89)	122.8 (120.4-125.2)	1280	400, 520, 640, 780 920, 1040, 1160, 1440, 1560, 1680
Cut #2	710.6 (647-831)	82.2 (74-94)	114.5 (109.8-119.6)	1400	520, 640, 760, 880, 1000, 1260, 1520, 1640, 1760, 1880

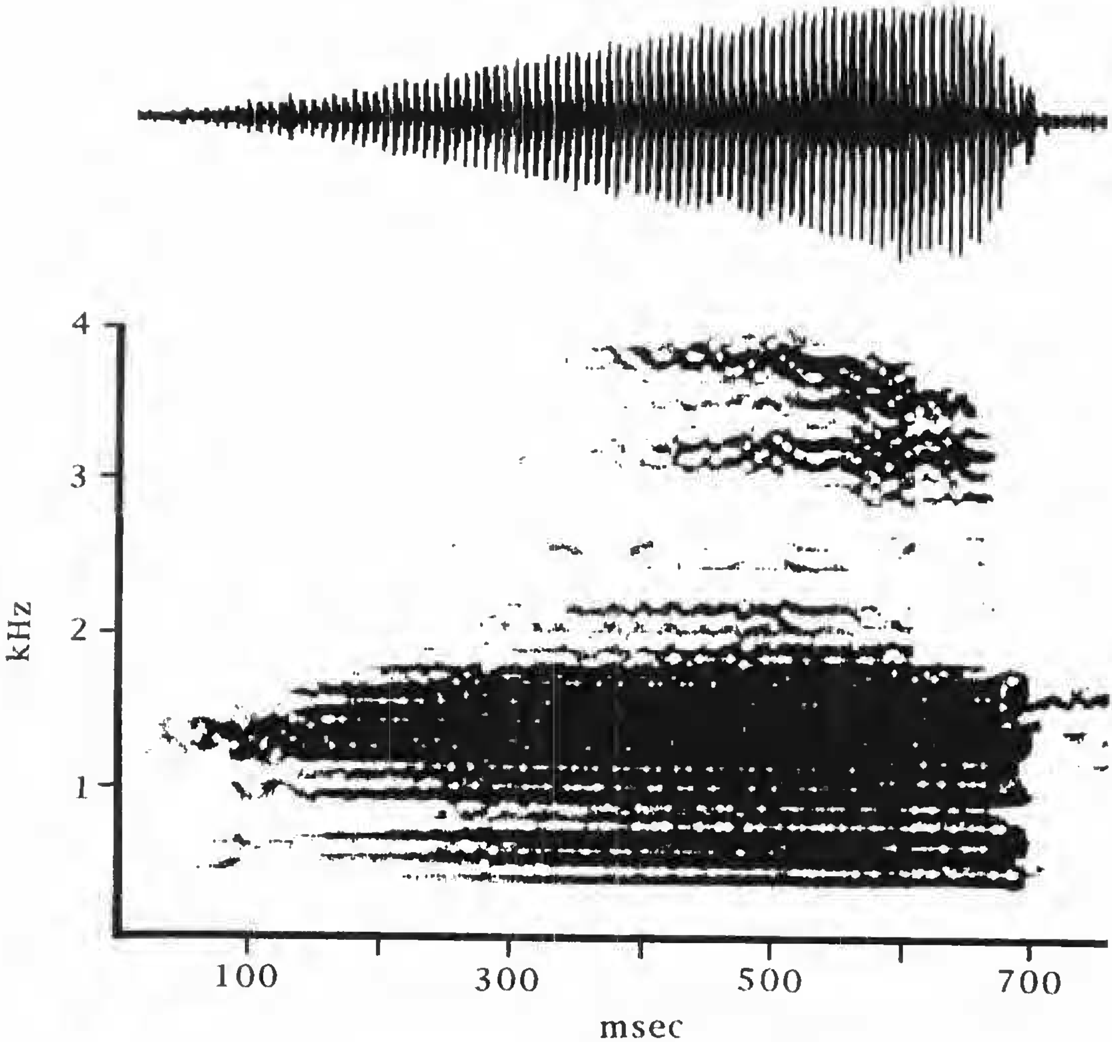

Fig. 1. Wave-form (upper) and audiospectrogram (lower) of the call of *Litoria splendida* recorded in Hidden Valley, Kununurra Western Australia. Wet-bulb air temperature at the calling site, 25.1° C. Note that the ordinate of the wave-form display is not labelled because it depicts a relative linear scale in volts. The apparent vertical discontinuity at around 600 ms on the audiospectrogram is an artifact of the printing process.

TABLE 2. *Attributes of a representative call of* Litoria caerulea *recorded in Hidden Valley National Park, Kununurra Western Australia.*
Temperatures at the calling site were A_D= 25.5° C and A_W= 25.1° C.

Call Duration (ms)	No. of Pulses	Pulse Repetition Rate (p s^{-1})	Dominant Frequency (Hz)	Other Notable Frequencies (Hz)
210	32	147.6	1440	440, 580, 720, 1140, 1300, 1580

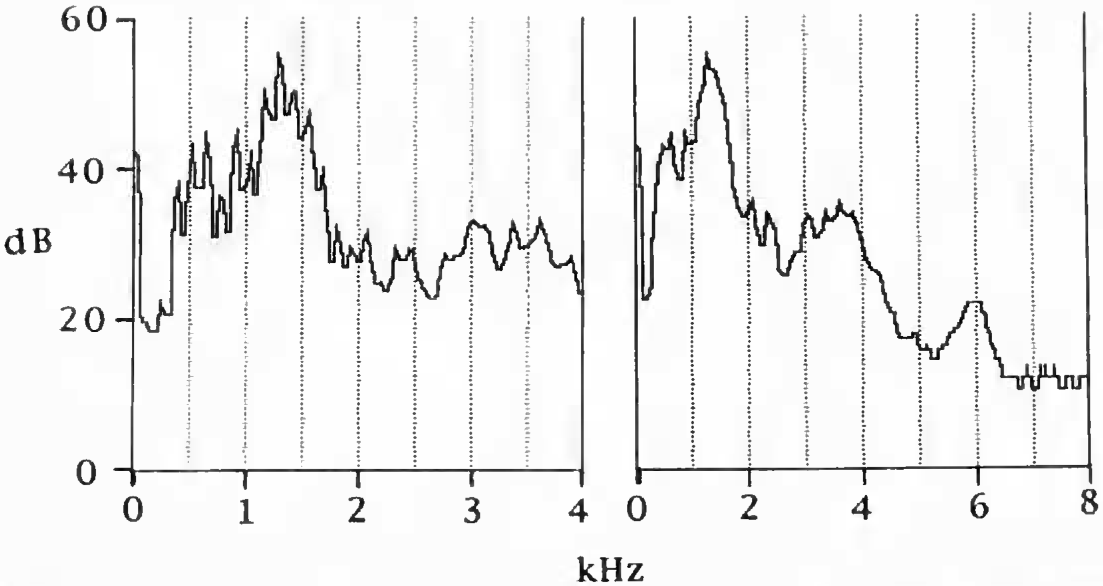

Fig. 2. Power spectra of the call of *Litoria splendida* across two ranges of frequency: 0 - 4 kHz, to show details of energy peaks and 0 - 8 kHz, to show that there is relatively little energy in the call above 4 kHz.

of approximately 120 Hz. Many of these frequency components result from amplitude modulation of a harmonic series generated by the vocal cords because the interval between components is nearly identical to the pulse repetition rate. Because of resonating and filtering characteristics of the sound-producing structures of the emitter, some of these frequency bands are emphasized, particularly those around 520 (? the fundamental frequency of the call), 640, 900, 1280, 1420 and 1540 Hz (slight variations around modal values occur because frequency values are measured in 20 Hz steps on the digital sonagraph). These spectral modifications make it difficult to determine confidently which components are part of the harmonic series and which are side bands arising from amplitude modulation. The frequency band with most energy (dominant frequency) differed between the two recorded males (1280 for male #1 and 1400 for male #2), with no within-individual variation (within the resolution of this analysis) found in the five calls of each male that were analysed. Although the call includes spectral energy peaks across a large frequency range (from around 500 to 4000 Hz), little energy is present above 4 kHz (Fig. 2).

Chorus structure

Although only three other species were calling in chorus with *L. splendida*, the chorus structure is of particular interest because the morphologically, behaviourally and ecologically similar species, *L. caerulea*, was a conspicuous component (Fig. 3). Attributes of a representative call of syntopic *L. caerulea* are listed in Table 2 and a wave-form

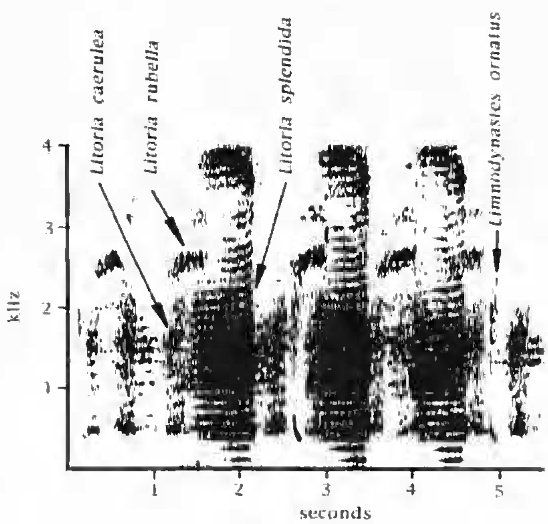

Fig. 3. Audiospectrogram of part of the chorus of four species recorded in Hidden Valley, Kununurra Western Australia. In this recording *Litoria splendida* has the loudest call, with backgound calls of *L. caerulea*, *L. rubella* and the very short call of *Limnodynastes ornatus*. Effective temperatures for calling males were: wet-bulb air temperature (*L. splendida*, *L. caerulea*, *L. rubella*), 25.1°C and water temperature (*L. ornatus*) 26.3°C.

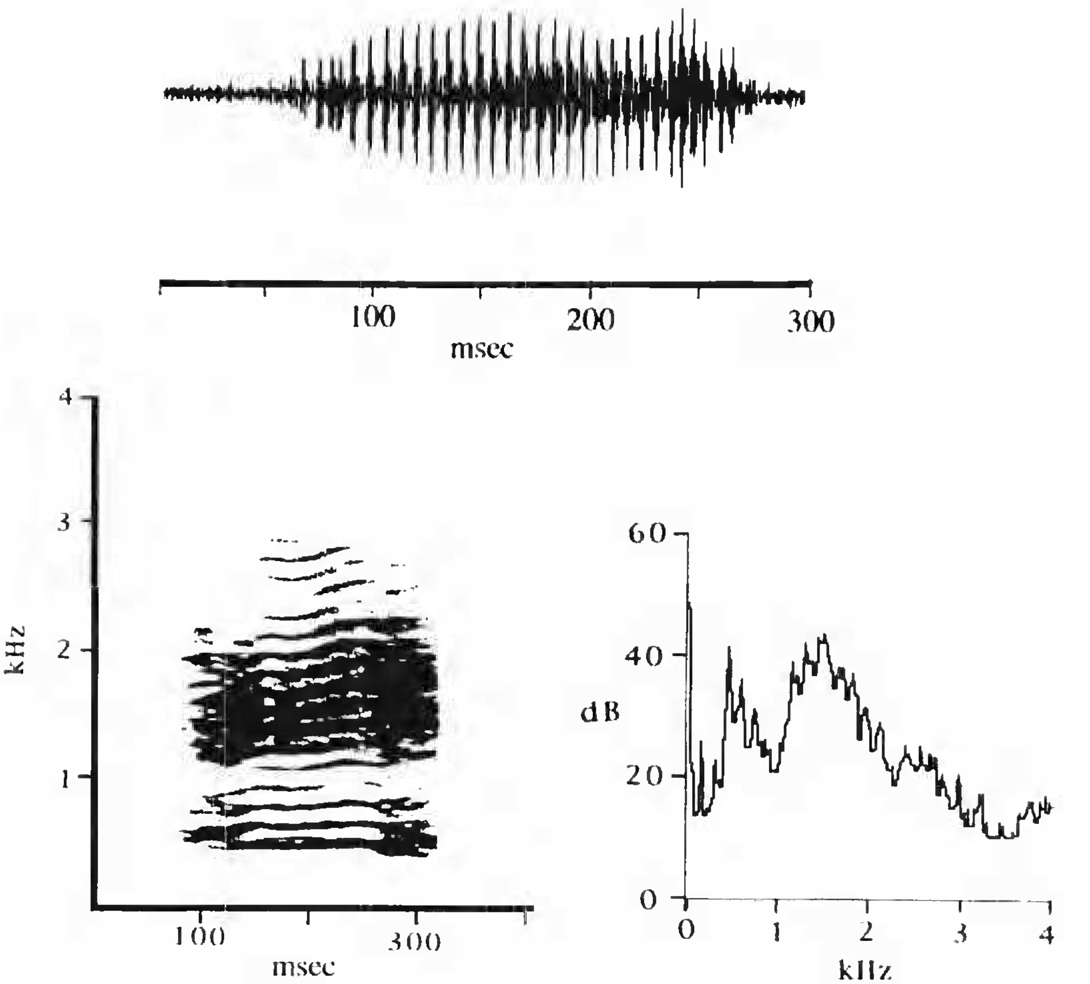

Fig. 4. Waveform, audiospectrogram and power spectrum of the call of *Litoria caerulea* recorded in Hidden Valley, Kununurra Western Australia. Wet-bulb air temperature at the calling site, 25.1° C. Note: (i) the different temporal scales on the wave-form and spectrographic displays; (ii) that the ordinate of the wave-form display is not labelled because it depicts a relative linear scale in volts.

display, spectrogram and power spectrum are shown in Fig. 4. The call has a similar dominant frequency and broad spread of peaks of energy as that of *L. splendida*, but it is considerably shorter, has fewer pulses, a much faster rise time and less abrupt cut-off, as well as a higher call repetition rate (130 calls min^{-1}). To the human ear, the call of *L. caerulea* has a harsher, less well-tuned quality. Nevertheless, because of the broad spectral overlap between these two large species and their use of similar calling positions there is the potential for significant acoustic interference between them.

Our observations of calling and breeding in *L. splendida* do not support the previous speculation that this species breeds only in the early wet season. Although our observations were made in mid-January, the wet season of 1996-97 was well established, two cyclones/rain depressions having already passed over the Kununurra area in the preceding four weeks (pers. obs.). During our visit, heavy afternoon rains fell on most days and this stimulus appeared to trigger calling and breeding in *L. splendida*. Successful reproduction also requires a continuous aquatic habitat for larvae to complete their development and it is likely that *L. splendida* will successfully recruit new individuals to the population only during wet seasons that have sufficient regular rainfalls to maintain temporary ponds. Although we have no information on the ultimate fate of larvae from the breeding episode reported here, it is likely that the pond in which breeding took place remained in existence for much of this season, which was marked by substantial and regular rainfall. This outcome contrasts with the calling and possible breeding reported by C. Done from a nearby site in Hidden Valley. When this site was visited by one of us (GFW) a short time afterwards, no free water was present and larval development would have been impossible. From this experience of the unpredictable rainfall patterns of this area, even in the "wet" season, it is possible that successful reproduction in *L. splendida* is a relatively uncommon event.

Acknowledgments

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